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Agriculture: International Engine of Economic Advance

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AGRICULTURE: INTERNATIONAL ENGINE OF ECONOMIC ADVANCE

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Every Canadian who owns a television set or reads a newspaper is familiar with the immense suffering inflicted upon millions of Africans during the last 15 years. Although long periods of inadequate rainfall are familiar to the arid and semi-arid regions of Africa, the recent droughts have been more devastating in their intensity, extent and persistence than any previously recorded. The African nations are among at least 1500 million, a quarter of the world's population, that exist permanently on the razor edge of survival. Of the more than 3 billion people living in what are classed as the least developed countries, more than 1500 million lack access to adequate medical care and live lives continuously haunted by the spectre of disease, hunger and malnutrition. While the degrees of poverty and underdevelopment vary significantly among the developing nations of Africa, Asia, Latin America and most of the Middle East, their standard of living and access to resources contrasts starkly with those of their wealthier world neighbors in North America, Europe and Oceania. Table 1 illustrates the extent of these disparities.

The developed countries with only a little over a quarter of the world's population use more than 60% of the world's commercial energy; control more than 90% of the world's research; and publish roughly 90% of all its books. The developed countries consume 50% more food calories per capita than the less developed. The developed countries enjoy a massively favorable balance of trade with the less developed; exports from the developed to the developing countries now exceed US $300 billion, representing more than one-third of the developed countries' total exports.

It is probable that at least one industrial job out of every six in the United States depends upon its exports to Third World countries. Table 2 shows that by the end of the decade the

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developing countries' populations will have increased from roughly three-quarters to four-fifths of the world's total. These numerical averages do not reveal some important demographic changes that are also occurring. The populations of the developed countries are progressively aging; those of the developing countries are relatively much younger. During the past half decade the proportion of Canadians under the age of 15 has decreased by 7% while those over 65 years of age has increased by 18%. Older people have smaller appetites than those who are young and active. Consequently, per capita and possibly total food demand will decline among major food producers such as Canada and the United States while the poorer nations with larger, younger populations will inevitably demand more. Though the rate of population increase will continue to vary significantly among different countries, there are more than 30 developing countries whose population growth rates will continue to exceed 3% per year for some time to come. Most of these are to be found in Latin America, the Middle East and Africa.

PROGRESS IN FOOD PRODUCTION

The 1960s saw a significant increase in per capita food production throughout the world, particularly in Asia, Latin America and the Middle East. The crude averages for all developing countries suggests that over the past 25 years food production per capita has been increasing at about 0.5% per year. These averages are, however, misleading in that they conceal wide variations among countries and among crop years. Figure 1 shows the indices of per capita food production over the last two decades and illustrates clearly the improvements in Latin America and Asia and the serious decline in sub-Saharan Africa. Figure 2 illustrates the debilitating effect wrought by drought in 24 sub-Saharan countries.

Tables 3 and 4 show significant disparities among African countries indicating the influence of poverty upon food production and upon general health.

The 1960s and early 70s were illustrative of the remarkable progress that can be made in countries whose governments recognize agriculture as of prime importance and highest priority. At the beginning of the 60s India was dependent upon massive injections of food aid. India is now a surplus producer and grain exporter. The progress made in the People's Republic of China in agricultural production, since the aberrations of the Cultural Revolution came to and end, are indeed spectacular. Increases in agricultural production are achieved either by higher levels of productivity per unit area of land, i.e. increased yields, and/or by expanding the area of land under cultivation. Most impressive in achieving the increased cereal production, particularly in Asia, have been the high yielding wheat and rice cultivars where, by the late 1970s, roughly 72% of the land under wheat and more than a third of the land under rice cultivation were sown to the so-called high-yielding varieties (HYV) which had their origins in the research of the International Maize and Wheat Improvement Centre (CIMMYT) and the International Rice Research Institute (IRRI).

DESTRUCTION OF ARABLE LAND

All other things being equal, probably the most critical factor relevant to the population and food equation in the developing countries is the number of persons to be fed from each unit area of farm land. Over the past decade in the developing countries the number of people to be fed per hectare of crop land has increased from three to four and, by extrapolation of present population trends, by the end of the century every arable hectare in the developing world will need to support between 5 and 6 people. Tables 5 and 6 show the rate at which arable land per capita is declining. As with all other resources, the availability of land per capita varies significantly among countries. For example, whereas in Mexico there are roughly three persons per arable hectare, the numbers in Egypt, Kenya and the People's Republic of China are respectively 16, 10 and 7.5. By the end of the century the numbers respectively for the same three countries will be 22, 15 and 10. The situation in Egypt is so serious that for some years IDRC has been supporting a project of desert reclamation in order to restore land close to the Nile to some of its earlier fertility.

One of the most tragic and serious of man's follies is his disposition to destroy and pollute his most valuable resources. Several recent reports by Environment Canada and the Canadian Environmental Advisory Council have drawn attention to the alarming rate at which we in Canada are destroying our most vital and irreplaceable resource: our productive farm land. The impact of salinization, soil erosion, the depletion of soil organic matter and plant nutrients, because of inappropriate cropping and poor soil management, in addition to the widespread destruction of arable land by urban spread,are a worldwide phenomenon. It is calculated that annually some 15 million hectares of arable land are destroyed, roughly half by urban spread, highway construction and strip mining. Consequently, there is an immediate and urgent need in every part of the world to prevent further depredation and destruction of arable land and to develop farming systems that give optimum yields without destroying or seriously depleting the soils' essential qualities and nutrients. Only 3% of the total earth surface is considered arable. The total loss to urban spread could, on conservative estimates, produce sufficient cereal calories for close to 70 million adults per annum. The average annual increase in world population amounts to nearly 70 million persons per year. Therefore our most urgent priority should surely be to protect and conserve the land already available from further destruction.

Reclamation of once fertile land that has been destroyed or debased, even where this is possible, costs considerable more than the conservation of what is already under the plough.

For most of the millenia since settled agriculture began increased food production has been achieved principally by expansion of cultivation onto virgin lands. In spite of all the evidence to the contrary, even in North America there seem to be many who labour under the delusion that fresh untapped land resources are virtually inexhaustible. It is however abundantly clear that in most nations, particularly the developing countries, additional production will not be realized from unused lands. Many of the best agricultural soils are already under the plough. Much of the so far uncultivated land is of marginal quality, inferior for agricultural crop production and ecologically fragile. Nor can improvement in tropical agriculture be realized by transferring more efficient production technologies from the temperate climates. A typical developing country farmer has at best fewer than 5 hectares at his disposal. In such heavily populated countries as Bangladesh and the People's Republic of China less than 2 hectares per farm family are by no means untypical.

In spite of his ecologically inferior resources the yields of food crops achieved by most developing country farmers are significantly lower than what are demonstrably possible. It was with this in mind that the family of International Agricultural Research Centres (IARCs) sponsored by the Consultative Group on International Agricultural Research (CGIAR) was established. The contributions made by IRRI and CIMMYT to rice and wheat production have already been referred to and these two research centres have been the flag ships of the CGIAR system.

THE CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH (CGIAR)

The CGIAR, of which IDRC was a founding member, consists of an informal consortium of donor agencies and representatives of developing countries sponsored by the World Bank, the United Nations Development Program (UNDP) and FAO. The CGIAR now supports 13 research centres a list of which, with their respective responsibilities, appears in Table 7.

A more detailed account of the CGIAR and its family of IARCs is given in "The Fragile Web - The International Agricultural Research System", published by IDRC and CIDA, and in several publications of the World Bank. In this paper the activities of four members of the CGIAR family of centres will be briefly described. The CGIAR is a somewhat unusual and unconventional institution. It is a consortium of donors which operates without any legal charter, written rules, protocols or bylaws; membership is entirely voluntary and decisions are reached entirely by common consent, shared interest and general goodwill among its members. Each IARC is autonomous, with its own Board of Trustees, receiving its annual income from bilateral donations from CGIAR members. The CGIAR from its inception in 1971 appointed a Technical Advisory Committee made up of 13 distinguished scientists who regularly and continually review the scientific programs and technical progress of all of the IARCs. Each IARC prepares an annual program of work and budget which is reviewed by the TAC and the CGIAR members and each IARC is subject to an in depth management and scientific review every five years.

The CGIAR is now a major international organization dispersing more than US $190 M in 1984 in support of its 13 member IARCs. The 40 members of the CGIAR represent both developed and developing countries and a variety of governmental and non-governmental donor organizations.

The IARCs are sometimes accused of destroying or reducing the world's germplasm resources. In fact, the centres responsible for crop improvement, together with the International Board for Plant Genetic Resources (IBPGR) have greatly increased and classified the germplasm collections of the world's most important food crops. (Table 8)

The four centers which will be briefly described in this presentation are:

1. The International Rice Research Institute (IRRI)
2. The International Center for Agricultural Research in Dry Areas (ICARDA)
3. The International Laboratory for Research in Animal Diseases (ILRAD)
4. The International Potato Center (CIP)

These have been chosen to illustrate the wide variety of crops and agricultural research activities and the different styles of operation followed by different IARCs.

INTERNATIONAL RICE RESEARCH INSTITUTE (IRRI)

IRRI was the first of the IARCs to be established having started its work in 1962 from its headquarters location at Los Banos in the Philippines.

Rice is the most important cereal for the poorest nations of the world. The total world production is 440 million tonnes of which 90% is grown in Asia. The largest single national producer is the People's Republic of China (PRC) which produces 170 M tonnes, more than 25% of the world's total. Rice production in the PRC has increased by more than 30% over the last five years, largely through the introduction of HYVs and improved rice-based cropping systems. The notable character of the HYVs is their short stature, more of the photosynthesized biomass being located in the head of grain than in the stalk. This dwarf-like character yields more edible grain per hectare than the earlier traditional taller varieties.

Furthermore, the short, stiff straw of the dwarf types renders them more resistant to lodging than their taller relatives.

The first short straw HYV rice to be distributed from IRRI was IR8. It had two parents: (1) Peta - a tall Indica from Indonesia with high vigor, seed dormancy and resistance to several diseases; and (2) Dee-Geo-Woo-Gen - a short Indica from Fukien in China which was high-yielding, heavy tillering but of short stature. While IR8 had the advantage of comparatively high yield, it was susceptible to many diseases and the grain was of a quality unacceptable in many parts of Asia. Since IR8 appeared 20 years ago, IRRI's germplasm bank has increased from a few hundred to 75,000 accessions in 1984. Thousands of crosses have been made leading eventually to IR36 which was produced by gene pyramiding of 11 parents including one wild species Oryza nivera. In addition to its short stature and high yield, IR36 demonstrates wide tolerance to pests and diseases. The parentage of IR8 and IR36 are shown in Figures 3 and 4.

Rice is of course an aquatic plant and the highest yields have been achieved from the short straw types grown in relatively shallow flooded bunds. In several parts of Asia rice is grown in deep flooded land and improved varieties into which an elongation gene has been introduced can grow faster than rapidly rising water thus keeping their heads above water as deep as 1 metre. Some types are even able to survive several days submerged underwater.

Cropping Systems Research

Throughout the tropics where there is no winter frost, and wherever water can be provided whenever needed, plants will grow all year round. Consequently, to make most productive use of land, genotypes which mature rapidly are as important as those which yield a high proportion of grain to straw. Fast maturing short term types permit two or more crops to be harvested on the same land during the same year. A combination of higher yielding, gaster maturing rice types enabled the Philippines to more than double its rice production in two decades without any significant increase in the area under cultivation. Fast maturing rice types have made possible highly productive multiple cropping systems, multiple cropping being defined as a system in which two or more crops are grown simultaneously (intercropping), sequentially, or in rotation throughout the year. By and large smallholders make more efficient use of land than monocrop farmers in the tropical developing countries.

Since the early 1970s IDRC has supported pioneering research on rice-based cropping systems. Funds were provided through IRRI for the Asian Cropping Systems Network (ACSN) and directly to six member countries: Philippines, Indonesia, China, Thailand, Bangladesh and Sri Lanka. A good example of the growth and development of the cropping systems research within this network is provided by the national program in the Philippines. Starting in 1972, the University of the Philippines at Los Banos (UPLB), with support from IDRC, conducted research on multiple cropping and its adoption by farmers in six selected communities. The farmers' response was enthusiastic and adoption of the recommended multiple cropping technology was rapid, resulting in substantial improvements in both productivity and the nutritional status of the target communities. Between 1972 and 1976, the number of cooperating farmers rose from 29 to 656, their crop intensity index rose from 1.65 to 2.1 and their multicropped area rose from 48% to 75%. This project was renewed for three phases and the Philippines has now developed its own internal network for cropping systems research with more than 100 national research sites in 1984.

The essential components of multiple cropping systems, or farming systems research as it is now more commonly called, are shown diagramatically in Figures 5 and 6. IDRC's support for rice-based cropping systems research at IRRI began in 1972. By 1975 a small Asian regional cooperative cropping systems network consisted of two countries; the Philippines and Indonesia, and five experimental sites. The IRRI ACSN now embraces 12 Asian nations and close to 50 principal experimental sites. The essential of cropping systems research is that it begins, continues and ends with the family farm. At the outset a detailed assessment is made of existing and traditional cropping systems together with an evaluation of the typical farmer's resources, opportunities and constraints. Principal test sites are selected to be typical of large agroclimatic areas in which smallholder producers have their farms.

Having determined what are typical systems in each of the major agroclimatic zones, cropping systems experiments are carried out on modified and hoped for improved production technologies both at the test sites and in farmers' fields. Experiments include examination of alternative cropping patterns, of improved varieties, of fertilizer, pest and weed control regimens. Among the 12 nations: Bangladesh, Burma, China, India, Indonesia, Korea, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, and Thailand, which are the participants in the Network, there are now close to 200 rice-based farming systems research sites from which the results are compared at an annual meeting of the participants held each year in a different country.

Different cropping patterns have been tested under a range of irrigated and rainfed conditions with various legume and other cereals grown either before or after the rice crop. To mention only a few at random, in Bangladesh such patterns as (a) rice-rice; (b) chickpea-rice-rice; and (c) wheat-rice-rice are under study; in Burma long term fertilizer trials are in progress using (a) rice-wheat-sesame; (b) mung bean-rice-sunflower; and (c) maize-rice-soybean cropping patterns. In the PRC different cropping patterns include barley-rice-maize; rapeseed-rice-soybean, rice-soybean and maize.

With support from IDRC, UPLB has cooperated with IRRI in the breeding of ideotypes and phenotypes each with an architecture and growth habit that can conveniently fit into a particular cropping pattern. In cooperation with IRRI, UPLB has also implemented some innovative graduate study programs in which eight or more graduate students working as a team in the same rural areas produce overlapping theses ranging from plant breeding and agronomy to rural sociology.

Another innovative feature of the IRRI farming systems program has been evaluation of farmers' inputs, outputs and constraints. In many cases the evaluators are the farmers' children who are trained to make daily year-round records of such factors as time spent in planting, weeding and harvesting; investment in fertilizers and other crop chemicals; yields and returns to the farmers' land and labour. Because of their importance as sources of draught power, milk, meat and manure, livestock have recently been added to the Asian farming systems network program.

INTERNATIONAL CENTER FOR AGRICULTURAL RESEARCH IN DRY AREAS (ICARDA)

IDRC has had a close association with ICARDA and its progenitor the Arid Lands Agricultural Development Program (ALAD). On behalf of the other members of the CGIAR, IDRC acted as Executing Agency for the establishment of ICARDA and the start up of its important program. ICARDA was created in 1977 to serve the needs of the low rainfall countries of the eastern Mediterranean, the Middle East and north Africa and their immediate neighbors. The total population exceeds 300 million and more than two-thirds live in countries where per capita GNP was less than US $1,000 in 1980. Originally ICARDA was intended to operate from three stations: a main station in the B'qaa Valley in the Lebanon; a highland station in Tabriz, Iran; and an ancillary station close to Aleppo in Syria. This original plan was totally frustrated by subsequent political upheavals and ICARDA now operates from headquarters and a main station at Aleppo.

The food legumes, faba beans, chickpeas and lentils, though staples in diets of most of the people of the region, in common with most other food legumes have been relatively neglected by plant breeders and agronomists until comparatively recently. With IDRC support, ALAD began a regional food legume research program in 1973. When ICARDA came into existence this program was significantly expanded. When the IDRC-supported program started in 1973 there were less than 10 scientists of the region trained to work on food legumes. Today there are well over 100. ICARDA has collected, categorized, field tested and disseminated a very wide range of improved faba bean, lentil and chickpea germplasm. These three important food legumes are grown over 4 M hectares producing roughly 3 M tonnes per annum. As with most other legumes, until ICARDA's program got underway yields in farmers' fields were significantly below 1 t/ha. As a direct consequence of ICARDA's cooperative legume improvement and regional training programs, yields in cooperating farmers' fields of faba beans (_Vicia faba_) in Egypt and lentils (_Lens culinaris_) in Ethiopia have increased by more than 50%.

The eastern end of the Mediterranean is the natural home of chickpea (_Cicer arietinum_) where more than 1 M tonnes is grown annually. IDRC has supported germplasm collection expeditions by ICARDA into Afghanistan and Turkey which have greatly extended the germplasm base available for future plant breeding.

Traditionally chickpea is planted in the spring because the established varieties suffer frost damage and _Ascochyta_ blight when grown during the winter. In a cooperative program between ICARDA and the University of Manitoba chickpea types resistant to frost damage and _Ascochyta_ blight have been developed which now permit winter planting. Traditionally, legumes in the Middle Eastern region are planted in the early spring.

The training program at ICARDA deserves special mention not only for the number of qualified plant scientists it has generated but for its imaginative pattern of training. During ICARDA's intensive training courses each trainee follows the legume crops through all stages of initial seed selection, land preparation, planting, agronomic management and harvesting. They then select from the harvested seed those cultivars that seem best suited to their national requirements and conditions. The trainees then come together each year to exachange germplasm, and to relate to one another the progress made and the difficulties encountered.

It has been IDRC's style of operation to encourage and make possible the strengthening of national agricultural research programs through cooperation and association with the IARCs. In the Middle East and West Asia, in cooperation with ICARDA, IDRC has supported food legume research in Bangladesh, Egypt, Jordan, Lebanon, Sudan, Syria and Turkey and has enabled ICARDA to expand its North African program into the Maghreb countries of Algeria, Morocco and Tunisia.

INTERNATIONAL LABORATORY FOR RESEARCH IN ANIMAL DISEASES (ILRAD)

Established in 1974 and located in Nairobi, Kenya, ILRAD is unique among the family of IARCs first in being the only IARC responsible for research in animal pathology, second in that its research program is of a much more fundamental nature than the other CGIAR centres. The two devastating diseases which ILRAD's research hopes eventually to eradicate are trypanosomiasis and theliorosis, the former often being called "Sleeping Sickness", the latter more commonly called "East Coast Fever".

Meat protein production per hectare in Europe is more than 80 times and in Latin America almost 10 times what is achieved in Africa. In Africa animal diseases, particularly trypanosomiasis, are the greatest major constraint to increased production. Both trypanosomiasis and theliorosis are protozoal diseases carried by invertebrate vectors. Theliorosis is carried by various ticks; the vector for trypanosomiasis is the tsetse fly.

Tsetse-borne trypanosomiasis affects cattle in 37 countries of Africa covering an area larger than the United States. It is conservatively estimated that 150 M cattle, 225 M sheep and goats and 30 M other animals including camels and horses are seriously affected by trypanosomiasis. If trypanosomiasis were eliminated, stocking densities of cattle in West and Central Africa could increase from a present average of $3/km^2$ to more than $20/km^2$. Similar increases could be achieved with sheep and goats. The annual loss in meat production caused by trypanosomiasis in Africa exceeds US $3.5 billion, a figure which does not include the unrealized value of milk, hides, other by-products, manure and traction.

Trypanosomiasis is transmitted cyclically by about 30 species and sub-species of the tsetse fly which occupy habitats ranging from arid bush to dense rain forests, many in the tops of trees. The most widely abundant pathogenic _Trypanosome_ species are

T. congolense, T. vivax, and T. brucei. The trypanosomes are transmitted by the tsetse fly (Glossina spp.) which feed on the blood of infected animals. The infective trypanosomes taken up in the tsetse's blood meal undergo a complex cycle of physiological transformation within the fly's mid gut and proventriculus ending as metacyclic forms in the insect's salivary glands. When the tsetse carrying the pathogenic trypanosomes takes its next blood meal from an uninfected farm animal, the infective metacyclic trypanosomes are transmitted and as they undergo further metamorphosis in the animal's blood and tissue they cause trypanosomiasis with its typical symptoms of anaemia, emaciation, reproductive disorders and eventually death.

African trypanosomes have elaborated an ingenious method by which to escape from the immune responses of their infected hosts. The trypanosome antigens are carried on their surface coats. Each antibody developed by the infected animal's immune system acts to neutralize a specific trypanosome antigen. These surface antigens are glycoproteins which continuously change their biochemical structure. This ability of the trypanosomes to switch on synthesis of the protective surface glycoproteins appears always able to keep ahead of the animal's capability to develop protective antibodies. ILRAD's work suggests that a single trypanosome can progressively synthesize more than 100 different antigenic glycoproteins. Thus, for the immediate future, the chances of producing an effective vaccine against trypanosomiasis appear remote.

Treatment of herds with trypanocidal drugs has been the most effective method of controlling trypanosomiasis over the past 50 years. However, drug resistant strains are now encountered and the cost of developing new drugs is so high that no new trypanocidal drugs have been introduced during the last 20 years.

Some trypanosomes tend to form clumps within the animal's peripheral blood vessels so that only those on the outer surface tend to be affected by chemotherapeutics. Research at the University of Guelph has indicated that surfactants may be used to disperse these clumps and thus render the trypanosomes more susceptible to drug therapy.

For reasons as yet unknown many wild game and some domestic cattle such as the N'dama of the Gambia have evolved a high degree of immunity to trypanosome infections. The transferrance of this immunity between breeds is being studied at ILRAD.

Hormones such as gonadotropins can induce cows to release eggs from their ovaries. These may then be fertilized by artificial insemination before being flushed from the uterus for subsequent transplanting into surrogate mothers. Cryogenic preservation permits as many as 100 embryos to be transported in a freezer the size of a normal suitcase. When implanted the calf embryo acquires the immunities of its surrogate mother in addition to those acquired from its natural parent. ILRAD has been successful in transplanting trypanosome resistant N'dama embryos into more susceptible species such as the Boran cow.

Using advanced techniques of cell culture, monoclonal antibodies and DNA probes, light is gradually being shed upon the epidemiology of bovine trypanosomiasis and on the biochemistry of trypanosome antigenicity. Monoclonal antibodies can be used to recognize specific antigens isolated by immuno adsorbent columns. Simplified methods for propagating the metacyclic forms of the trypansomes _in vitro_ are being identified by analysis of parasite DNA. The mechanisms of resistance are being characterized by examination of various body cells believed to be involved in the animal's immune system.

For many years it has been believed that the wild game animals of Africa have evolved into immune reservoirs of the parasites which infect the exotic and domesticated species. For several years IDRC and CIDA supported an interesting cooperative project between the University of Guelph and the Government of Kenya and ILRAD in order to determine patterns of resistance in wild game animals together with possible vectors of transfer between the wild game and the domesticated species.

Though it would be unreasonable and unrealistic to anticipate the elimination of trypanosomiasis from Africa in the near future, the rapid development of new diagnostic tools and the abundance of new knowledge and greater understanding which ILRAD has acquired during its relatively short life offer considerably greater hope of improved control in the years ahead.

While supporting research on the control of animal pathogens, IDRC has by no means neglected the improvement of animal production systems. In cooperation with the International Center for Tropical Agriculture in Colombia a large network of tropical pasture improvement projects has developed throughout Latin America. A very large collection of pasture grasses and fodder legumes are collected and test grown in single and mixed swards under different agroclimatic conditions before the best are submitted to controlled grazing. This pasture network extends from the humid lowlands of Panama to the High Andes of Peru where the indigenous alpacas and llamas can survive at altitudes in excess of 4,000 metres. These Andean camelids suffer a number of infectious and infestations similar to those encountered in African animals.

INTERNATIONAL POTATO CENTER (CIP)

Though the Centro Internacional de la Papa (CIP) was established in 1971 near Lima, Peru, it did not join the CGIAR system until sometime later.

The potato, a tuber bearing species of Solanum is indigenous to the highlands of Latin America and it is CIP's major aim to improve the potato both in its natural Andean habitat and to develop varieties and production systems adaptable to lower altitude tropical regions. Worldwide the potato is the fourth most important food crop after wheat, rice and maize. Only the sweet potato ranks higher in total energy production per hectare per day.

Over the past two decades potato production has increased by nearly 70% in developing countries. On a dry weight basis the nutritional value of potatoes is superior to whole wheat flour, protein being roughly equal, lysine double, sulphur amino acids roughly equal, and ascorbic acid significantly higher than what is found in an equivalent weight of whole wheat flour. The main disadvantage of the potato is that it is propagated from seed tubers which are bulky, costly to transport, and subject to rapid spoilage in tropical climates.

CIP's world potato collection includes 5,000 classified cultivars and more than 1500 wild accessions which when examined collectively display an enormous range of genetic diversity. To overcome the many disadvantages of tuber propagation, since 1977 CIP has been attempting to convert the genetic materials in its world collection from tuber seed to true botanical seed which can be stored almost indefinitely, remaining viable without annual replantings. True potato seed is much lighter and can be shipped at a fraction of the cost of tubers; only a few grams of true seed being required to replace the 3 tonnes of seed tuber required to plant 1 hectare. True seed can be stored for long periods of time and propagated at whatever time suits the farmer's cropping pattern system.

The world average yield of potatoes is about 14 t/ha and roughly 10 t/ha in developing countries. In on-farm experiments yields in excess of 40 t/ha have been achieved from true potato seed. Since propagation from seed can be realized at any time of the year, potatoes can be intercropped with other species. For example, intercropping potatoes with sugarcane maintains a lower soil temperature which favours tuber bulking close to the time of maturity.

However, all genotypes and cultivars do not readily set seed and a great deal of work still remains before true seed will eventually replace tubers as potato planting material. Another alternative is vegetative propagation from shoot and root meristem which though empirically derived is now making significant progress. CIP has designed containers and procedures for the air shipment of meristem plantlets.

More than any other IARC, CIP has sub-contracted its research to other institutions in both developing and developed countries. Broadly speaking the more advanced institutions undertake studies that require advanced skills and expensive equipment.

The advantages of contract research are several. Work in developing country institutions is considerably less costly than at an international centre where the cost of maintaining an expatriate scientist is now close to $150,000 per year. Furthermore, sub-contracting strengthens the indigenous capabilities of the developing country research institutions. Research contracted to more advanced countries gives an IARC access to a much wider range of professional competence and experience than it could possibly employ within its own institutional walls.

THE INFLUENCE AND IMPACT OF THE CGIAR IARCs

A team of experienced scientists is just completing an extensive study of the impact of the IARCs upon agricultural production in developing countries. Though the complete analyses and comprehensive observations of their findings are not yet available, certain trends and clear indications are evident. In those countries whose governments assign a truly high priority and do not simply pay lip service to the importance of agriculture, investment in agricultural research has a very substantial payoff. From the CGIAR system the most evident tangible benefits come from the semi-dwarf wheat and rice varieties provided by research at CIMMYT and IRRI. The former are grown over 35 M hectares (45%), the latter over 70 M hectares (55%) of the areas sown to wheat and rice respectively throughout the developing world. The high yielding wheat and rice varieties produce at least 50 M tonnes more than would have been realized from the traditional types.

The acceptance by developing country farmers of other IARC crop cultivars is less readily apparent though there is evidence that in addition to the legumes developed at ICARDA and described above, other IARC developments are gradually finding their way into farmers' fields. Several IARCs are expanding their programs in Africa, the continent in greatest need of agricultural development.

At least as important as improved cultivars and production technologies are the IARC's training programs. In addition to many hundreds of conferences, seminars and workshops organized by the IARCs, more than 17,000 persons have been trained at international centres since 1962 and if off-campus training is added, the total of LDC trainees exceeds 27,000 of which nearly 2,000 have been awarded higher degrees.

While covering a broad spectrum the CGIAR IARCs by no means take account of all components and systems of rural food production, protection and utilization. As is shown in Table 9, 71% of the world's surface is covered by oceans and nearly 1% by natural fresh water. Though the area covered by forest represents less than 10% it generates close to 42% of the world's total annual dry matter production. Consequently, from its beginning IDRC has given considerable encouragement and investment to the cultivation of aquatic resources and to agroforestry.

AQUACULTURE

In his "History of Plants" Theophrastes, a pupil of Aristotle, reported how two crops of wheat and one of pasture was grown in the Euphrates Valley through the judicious use of irrigation. Similarly in Sri Lanka, two crops of rice can be grown annually, the first watered by the monsoon rains, the second irrigated from the ancient tanks, water catchments that have existed for over 1,000 years. In addition to providing irrigation water, in several of these reconstructed tanks, tilapia and carp are being cultured in floating bamboo cages. The floating cages, 2.5 m^3, are floated above natural algal blooms and stocked with *Tilapia nilotica* at about 600/cage. The fish receive supplementary feeding with rice bran and other agricultural by-products.

Throughout the developing countries there are some 600,000 km^2 of man-made reservoirs and impoundments used for hydro electric generation, flood control and irrigation. The Keban Reservoir in eastern Turkey, created by damming the Firat (Euphrates) River, has a surface area of more than 70,000 hectares. The first phase of a project supported by IDRC became operational in 1977, a year after the filling of the reservoir was complete. Eleven Turkish scientists were trained on short courses in Canada (Freshwater Institute, Winnipeg, and the University of Toronto) and in Eastern Europe in 1981. A complete limnological and fisheries survey of the reservoir was completed by 1981 and the results were used to set up a management regime for the reservoir, in particular the calculation of target stocking rates. Seven fishing cooperatives were licensed to exploit the reservoir in 1977 and by 1980 there were fourteen. Catches of food fish were 1,300 tonnes in 1983 and a total sum equivalent to $18,000 CAD was returned to the State in rents. Stocking of carp began on a small scale in 1982 with 60,000 fingerlings transported from hatcheries elsewhere in Turkey. By 1984, 300,000 young carp had been released and this scale will further increase with the construction of the Keban hatchery this year. Comparisons are now being made between free swimming species harvested by gill net and various species in cageculture.

AGROFORESTRY

On behalf of a consortium of donors IDRC was the Executing Agency for the creation of the International Council for Research on Agroforestry (ICRAF) which has its headquarters in Nairobi. ICRAF exists to improve land utilization and conservation by the protection of existing forest cover, and the introduction of tree species into small-scale farming systems and rural communities to provide food, feed, fuel and fertilizer in the form of leaf mulch. More than one-third of the world's population depend entirely upon wood to cook their food and heat their homes.

Every year throughout the developing world about 11 M hectares of forest; equivalent to nearly half the area of the United Kingdom, is destroyed, mainly to provide fuel for rural communities. At the present rate of deforestation tropical woodlands will be halved by the end of the century.

In addition to the products they provide, trees act as barriers to protect growing crops from searing winds and as soil stabilizers preventing erosion by wind and water.

Among the many agroforestry and social forestry projects supported by IDRC, two deserve special mention. Both are in progress in China.

Paulownia

In the PRC IDRC is supporting the improvement and greater use by breeding and management of the indigenous Paulownia, a tree which grows well on relatively poor soils. The project covers large and remote areas of Henan and Anhwei Provinces with a combined population of more than 120 M people. Much of the area is covered by light, sandy and in many places badly eroded soils. Though Paulownia is known to have been grown in the region for over 1,000 years, only recently has systematic breeding and silviculture been seriously studied. Paulownia puts down a deep root and survives well on poor soils and thus can be used as a perimeter around such crops as wheat, maize, cotton, sorghum and millet. In one commune alone over 1.7 M Paulownia trees have been planted as wind breaks.

Less than five years ago China had only 3,000 hectares of land planted with Paulownia trees, but since then the IDRC-supported project has transformed many parts of China literally into a Paulownia forest by intercropping 1.5 M ha of farmland and involving many rural peasants in one of the largest social forestry development projects in the world.

In addition to serving as a wind barrier around mono-crops or single row intercrops, Paulownia is grown in multi-storey systems, Paulownia providing the upper canopy below which are peach, apple and other fruit trees; grapevines and bush crops; and at the lowest level, root crops, legumes and medicinal plants.

Not only does Paulownia adapt well to various cropping systems, it can be propagated vegetatively or from seed. Four year old hybrids have produced close to 35 m^3/ha of timber. It possesses good structural properties, its fibre being so stable that it is used almost exclusively for the manufacture of stringer musical instruments. It is particularly gratifying to note that Mr. Zhu Zhao Hua, the scientist in charge of the Paulownia project, recently received the "Man of the Trees Award" presented by the Baker Foundation of Toronto, the Chairman of which is Dr. John Spinks, President Emeritus of the University of Saskatchewan.

Bamboo

Though botanically classified as a grass, bamboo is generally regarded as a forest plant. Since many species of bamboo flower and set seed only every 15 to 20 years, improvement by such conventional breeding practices as hybridization is extremely difficult. IDRC is supporting research to improve bamboo at the Institute of Subtropical Forestry in Hangchou in the PRC. There are two main types of bamboo: (a) the dispersive which push out spreading rhizomes from which new shoots emerge; and (b) the fascicular from which the culms emerge in dense clumps. The research project is seeking to identify types with a more frequent habit of flowering and is studying the effects of various agronomic practices upon yields and quality. Bamboo is one of the fastest growing plants. One instance was observed of a one year old culm 30 m tall and nearly 20 cm in diameter at the base. Throughout China bamboo covers more than 3.5 M hectares growing mainly between the latitudes of 18 and 35^{o}N. Though little systematic taxonomy has been recorded, there are probably more than 30 genera and over 300 species growing in China.

Bamboo has many uses: some types are grown for the edible young shoots which are harvested every second year; from others the culms are harvested and used for many structural purposes including building scaffolds, furniture, floating cages for fish culture, and as base materials for many artistic objects. One objective of the IDRC-supported project is to identify bamboo types which can tolerate winter frost and therefore be grown in the more northerly latitudes.

THE PLIGHT OF AFRICA

Of all the world's developing regions Africa is the poorest and the majority of its people enjoy little better than a barely subsistent existence. More than one-third of Africa is arid or semi-arid and roughly an equal area is relatively dry savanna. The recent droughts have been the most pervasive and devastating in history and have added severe stress to a group of nations seeking to establish stable governments and viable economies following their newly gained political independence.

Being well aware of the fragile ecology and uncertain rainfall, IDRC from its first year gave highest priority to the semi-arid tropics (SAT) of Africa. In addition to its support for research on the principal crops including sorghum, millet, cowpeas and other drought tolerant species, IDRC helped establish and has continued to support a network of agroforestry and social forestry projects around the Sahara and throughout the semi-arid regions of eastern and southern Africa.

In light of the rate of population increase, the heavy dependence upon imported food supplies, the decline and decay in some of its universities and training colleges, it is tempting to write off much of Africa as being beyond hope of human deliverance. And yet when one observes the spectacular turn around in agricultural production in the PRC and in India over the past decade, and when one observes what has been achieved in Zimbabwe since it gained independence, surely there is cause for hope. For example, in the PRC between 1979 and 1983, grain production increased by 16.6% while population increased by a little over 5%. During the same period cotton production more than doubled, oilseed crops increased by 52%, sugarcane by 55% and grain imports dropped by more than 28% between 1983 and 1984. In India, a country which in the 1950s and 60s was receiving enormous quantities of food aid from Canada and the United States, this year predicts a harvest that will yield surplus grain stocks of close to 30 M tonnes. In India since 1970 food grain production has increased by 60%, wheat by 150%, the principal oilseeds by 40%, tea, coffee and sugarcane by more than 50% and potatoes by nearly 200%. In Zimbabwe, even during the last year of drought, there was a significant increase in cereal production, almost all the increase coming from small and medium scale farms.

At a recent symposium on drought in Africa at which virtually all of the speakers were Africans or people who have worked most of their lives in Africa, the seriousness of the present food situation was frankly described. At the same time the recommendations made for short, medium and long term interventions if observed and implemented by the governments of Africa and the external multilateral, bilateral, governmental and non-governmental development agencies, can bring about the same kind of dramatic change which enlightened policy and persistant pursuit of appropriate priorities have achieved in India and the People's Republic of China.

Edmund Burke wrote "For evil to flourish it is necessary only for good men to do nothing". The publicity given to the drought in Africa led to an immense out-pouring of humanitarian goodwill. If this spirit of goodwill is maintained and if those responsible will pursue the recommendations made at the Ottawa symposium a new day can dawn for Africa, a day in which an adequate diet, produced largely from indigenous resources, will become a reality. It will also serve once again to demonstrate as has been demonstrated so often throughout history that the only reliable engine of economic and social development is agriculture.

TABLE 1

RESOURCES 1980

	DEVELOPED	DEVELOPING
WORLD POPULATION (%)	27	73
WORLD AGRIC. PRODUCTION (%)	62	38
WORLD CEREAL PRODUCTION (%)	88	12
WORLD COMMERCIAL ENERGY (%)	62	38
ENERGY IN AGRIC. SYSTEMS (% NATIONAL CONSUMPTION)	17 - 30	60 - 90
AVERAGE DAILY CALORIES/CAP	3300	2200
ARABLE LAND 2000 AD (Ha/CAP)	0.46	0.19

TABLE 2

POPULATION

	1980		2000	
	10^9	%	10^9	%
WORLD	4.4	100	6.2	100
DEVELOPED	1.2	27	1.3	21
DEVELOPING	3.2	73	4.9	79

TABLE 3

SUB-SAHARAN AFRICA

FOOD PRODUCTION

	Average annual growth rate of volume of production (percent) Food		Average annual growth rate of total production per capita (percent) Food		Index of food production per capita (69/70=100) average for 1980-82
	1960-70	1970-82	1960-70	1970-82	
Low income semiarid	2.1	2.8	-0.5	-0.1	85
Low income other	3.3	0.9	1.2	-1.4	86
Middle income oil importers	3.7	3.3	0.7	-0.6	91
Middle income oil exporters	1.1	2.4	-1.4	-0.3	92
Sub-Saharan Africa	2.5	1.7	0.2	-0.9	88
Industrial market economies					114

SOURCE; WORLD BANK 1984

TABLE 4

SUB-SAHARAN AFRICA

HEALTH RELATED INDICATORS

	Daily caloric supply per capita		Child death rate (age 1-4)	
	Total 1981	As % of requirement 1981	1960	1982
Low income semiarid	2,003	88	57	34
Low income other	2,001	86	37	22
Middle income oil importers	2,369	100	34	20
Middle income oil exporters	2,348	91	49	21
Sub-Saharan Africa	2,156	90	42	23
Industrial market economies	3,396	132	2	.5

Source: World Bank 1984

TABLE 5

ARABLE AREA PER CAPITA, ACTUAL AND PROJECTED (trend)

COUNTRIES	1951-55	1961-65	1971-75	PROJECTED 1985	PROJECTED 2000
INDUSTRIALIZED	.61	.56	.55	.50	.46
CENTRALLY PLANNED	.45	.39	.35	.30	.26
LESS DEVELOPED	.45	.40	.35	.27	.19
WORLD	.48	.44	.39	.32	.25

NOTE: ARABLE AREA INCLUDES LAND UNDER TEMPORARY CROPS (DOUBLE-CROPPED AREAS ARE COUNTED ONLY ONCE), TEMPORARY MEADOWS FOR MOWING OR PASTURE, LAND UNDER MARKET AND KITCHEN GARDENS (INCLUDING CULTIVATION UNDER GLASS), AND LAND TEMPORARILY FALLOW OR LYING IDLE.

SOURCE: THE GLOBAL 2000 REPORT TO THE PRESIDENT, VOL. 2, THE TECHNICAL REPORT. PREPARED BY THE COUNCIL OF ENVIRONMENTAL QUALITY AND THE DEPARTMENT OF STATE.

TABLE 6

ANNUAL WORLD LOSS OF ARABLE LAND

	MILLION HECTARES
URBAN AND INDUSTRIAL SPREAD	7.0*
MINERAL EXPLOITATION	1.0
EROSION	3.0
DESERT SPREAD	2.0
SALINITY, ACIDIFICATION, TOXICITY	2.0
TOTAL	15.0

*3 M HA IN INDUSTRIALIZED COUNTRIES

Compiled by J.H. Hulse

TABLE 7

International Agricultural Research Centres

Centro Internacional de Agricultura Tropical (CIAT), Apartado Aéreo 6713, Cali, Colombia. (Major research programs: cassava, field beans, rice, and tropical pastures)

Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), Londres 40, México 6, D.F., México. (Major research programs: maize and wheat)

Centro Internacional de la Papa (CIP), Apartado 5969, Lima, Peru. (Major research program: potato)

International Board for Plant Genetic Resources (IBPGR), Crop Ecology and Genetic Resources Unit, Food and Agriculture Organization of the United Nations, Via delle Terme de Caracalla, 00100 Rome, Italy.

International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 114/5055, Beirut, Lebanon. (Major research programs: farming systems; cereals; food legumes including broad beans, lentils, and chick-peas; and forage crops)

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), 1-11-256, Begumpet, Hyderabad 500016, A.P., India. (Major research programs: chick-pea, pigeon pea, pearl millet, sorghum, groundnut, and farming systems)

International Food Policy Research Institute (IFPRI), 1776 Massachusetts Avenue, N.W., Washington, D.C. 20036, USA.

International Institute of Tropical Agriculture (IITA), P.M.B. 5320, Ibadan, Nigeria. (Major research programs: farming systems; maize; rice; roots and tubers including sweet potatoes, cassava, and yams; and food legumes including cowpeas, lima beans, and soybeans)

International Livestock Centre for Africa (ILCA), P.O. Box 5689, Addis Ababa, Ethiopia. (Major research program: livestock production systems)

International Laboratory for Research on Animal Diseases (ILRAD), P.O. Box 30709, Nairobi, Kenya. (Major research programs: trypanosomiasis and theileriosis)

International Rice Research Institute (IRRI), P.O. Box 933, Manila, Philippines. (Major research program: rice)

International Service for National Agricultural Research (ISNAR), P.O. Box 93375, 2509 AJ, The Hague, Netherlands.

West Africa Rice Development Association (WARDA), E.J. Roye Memorial Building, P.O. Box 1019, Monrovia, Liberia. (Major research program: rice)

SOURCE: A Decade of Learning. IDRC 170e

TABLE 8

CROP GERMPLASM COLLECTIONS HELD AT GENEBANKS MAINTAINED BY THE IARCs

	CROP	ACCESSIONS	GENEBANK LOCATION
A.	CEREALS		
	RICE	60,000 8,226	IRRI WARDA
	WHEAT	50,000 17,000	CIMMYT ICARDA
	MAIZE	14,000	CIMMYT
	SORGHUM	24,000	ICRISAT
	BARLEY	13,000 10,000	ICARDA CIMMYT
	PEARL MILLET	14,340	ICRISAT
	MINOR MILLETS	3,700	ICRISAT
B.	GRAIN LEGUMES		
	COMMON BEAN	28,750	CIAT
	MUNGBEAN	5,000	AVRDC
	LIMA BEAN	2,300	CIAT
	LENTIL	5,400	ICARDA
	CHICKPEA	13,000 5,500	ICRISAT ICARDA
	PIGEON PEA	8,850	ICRISAT
	GROUNDNUT	8,800 2,500	ICRISAT IITA
	FABA BEAN	3,000	ICARDA
	COWPEA	12,000	IITA
C.	ROOT AND TUBER CROPS		
	CASSAVA	3,000 2,922	CIAT IITA
	SWEET POTATO	1,000 100	AVRDC IITA
	YAM	695	IITA
	POTATO	13,000	CIP

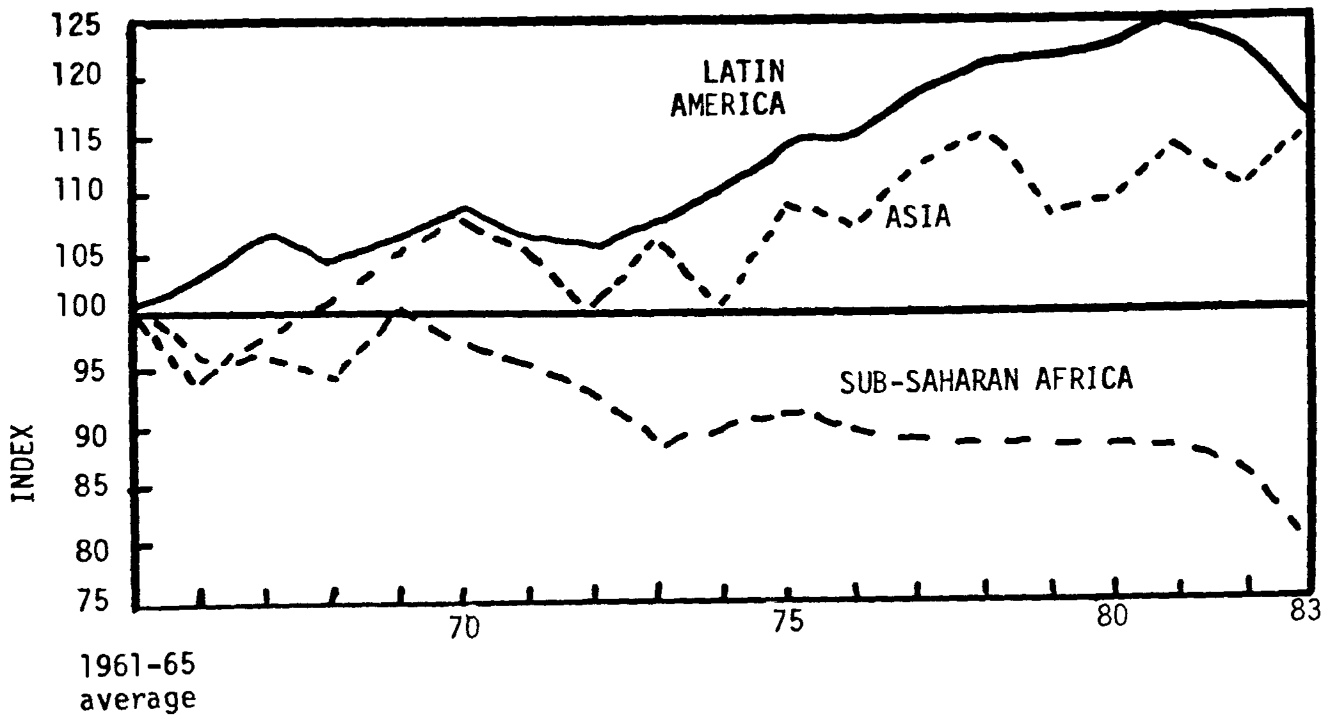
TABLE 9
EARTH'S ANNUAL PRODUCTION OF PRIMARY PHOTOSYNTHETIC BIOMASS

	AREA %	DRY MATTER/YEAR %
CONTINENTS	29.2	64.6
FORESTS	9.8	41.6
WOODLAND	1.4	2.7
SCRUB (INCL. TUNDRA)	5.1	1.5
GRASSLAND	4.7	9.7
DESERT (DRY & ICE)	4.7	0
CULTIVATED LAND	2.7	5.9
FRESHWATER	0.8	3.2
OCEANS	70.8	35.4
TOTAL EARTH	100	100
TOTAL AREA	510 M km^2	155 billion tonnes dry matter/year

FIGURE 1

INDEX OF PER CAPITA FOOD PRODUCTION: 1961-65 TO 1983

(1961-65 average = 100)

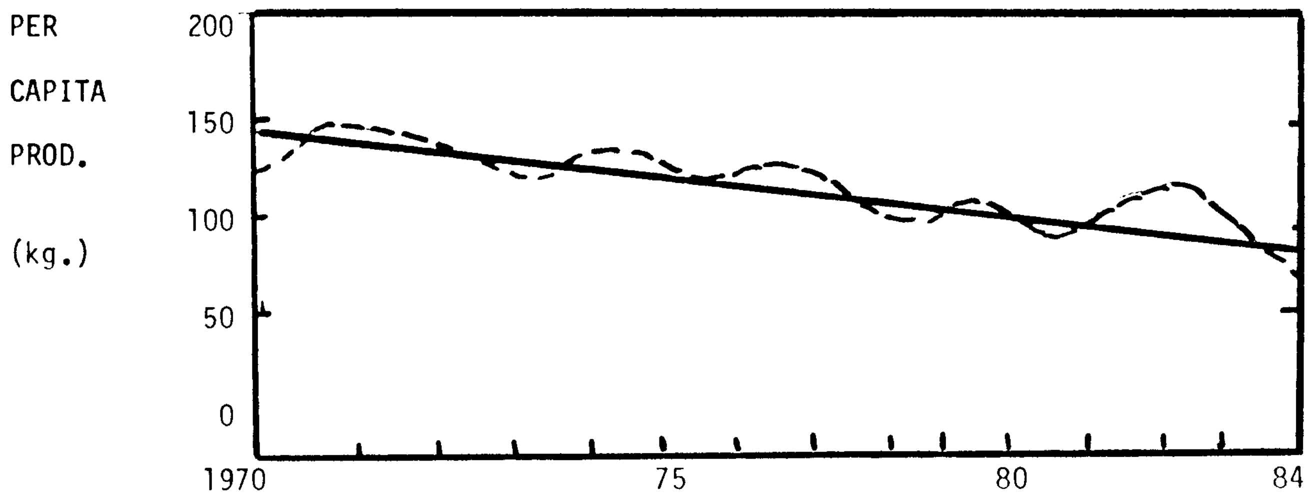


SOURCE: U.S. DEPARTMENT OF AGRICULTURE

FIGURE 2

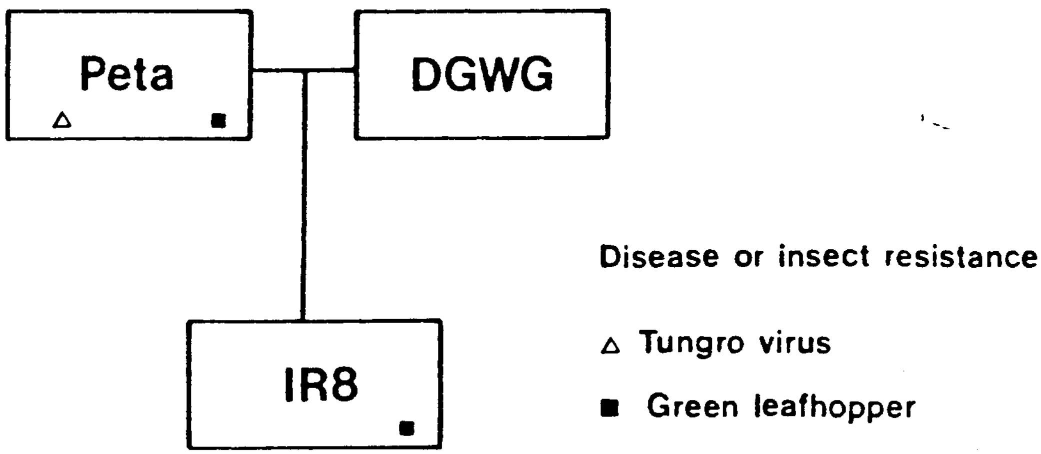
PER CAPITA GRAIN PRODUCTION IN TWENTY-FOUR COUNTRIES

AFFECTED BY DROUGHT 1970-84



SOURCE: FAO

FIGURE 3



PEDIGREE OF IR8

FIGURE 4

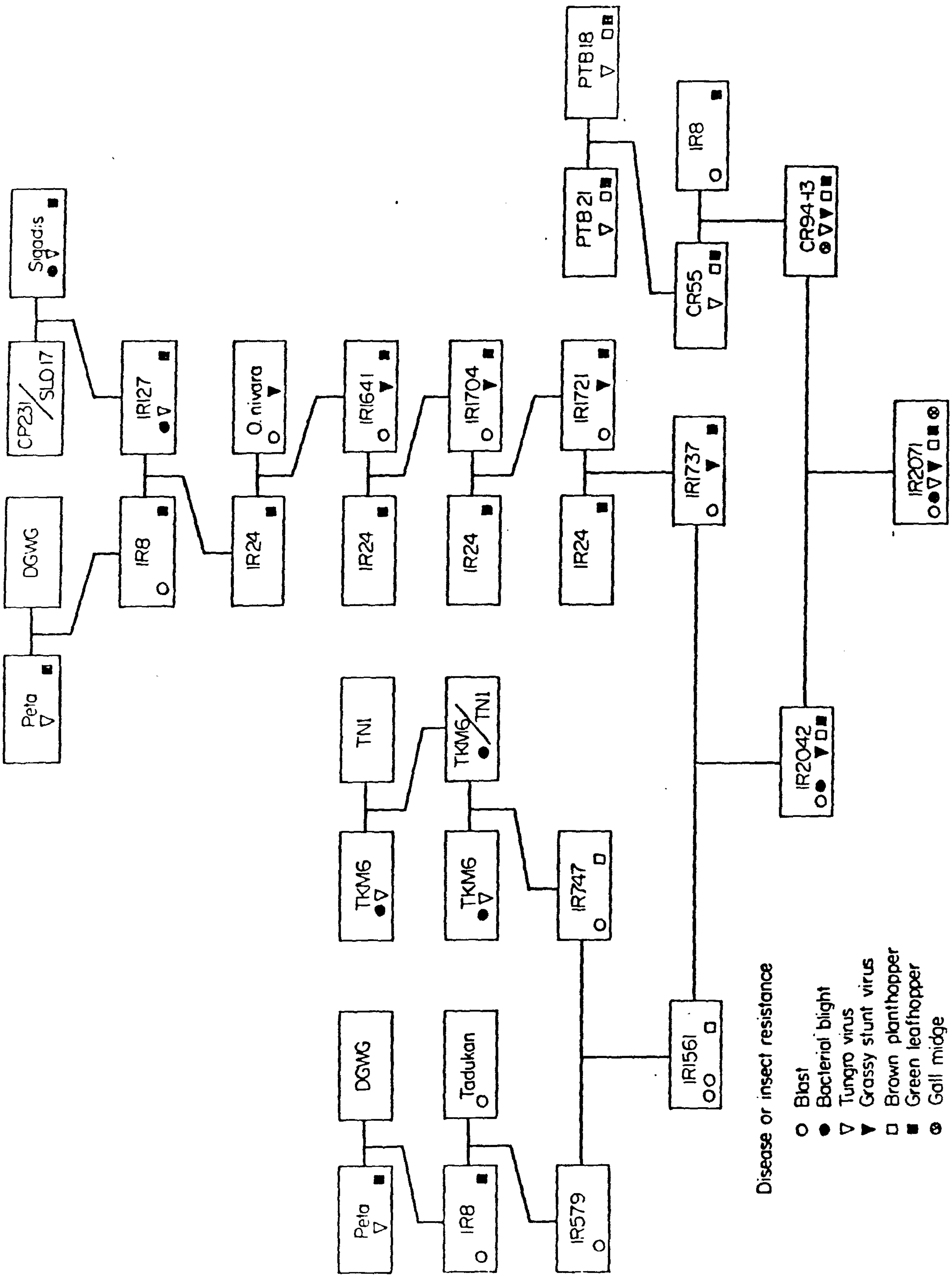


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FIGURE 5

COMPONENTS OF THE ON-FARM CROPPING SYSTEMS RESEARCH METHODOLOGY

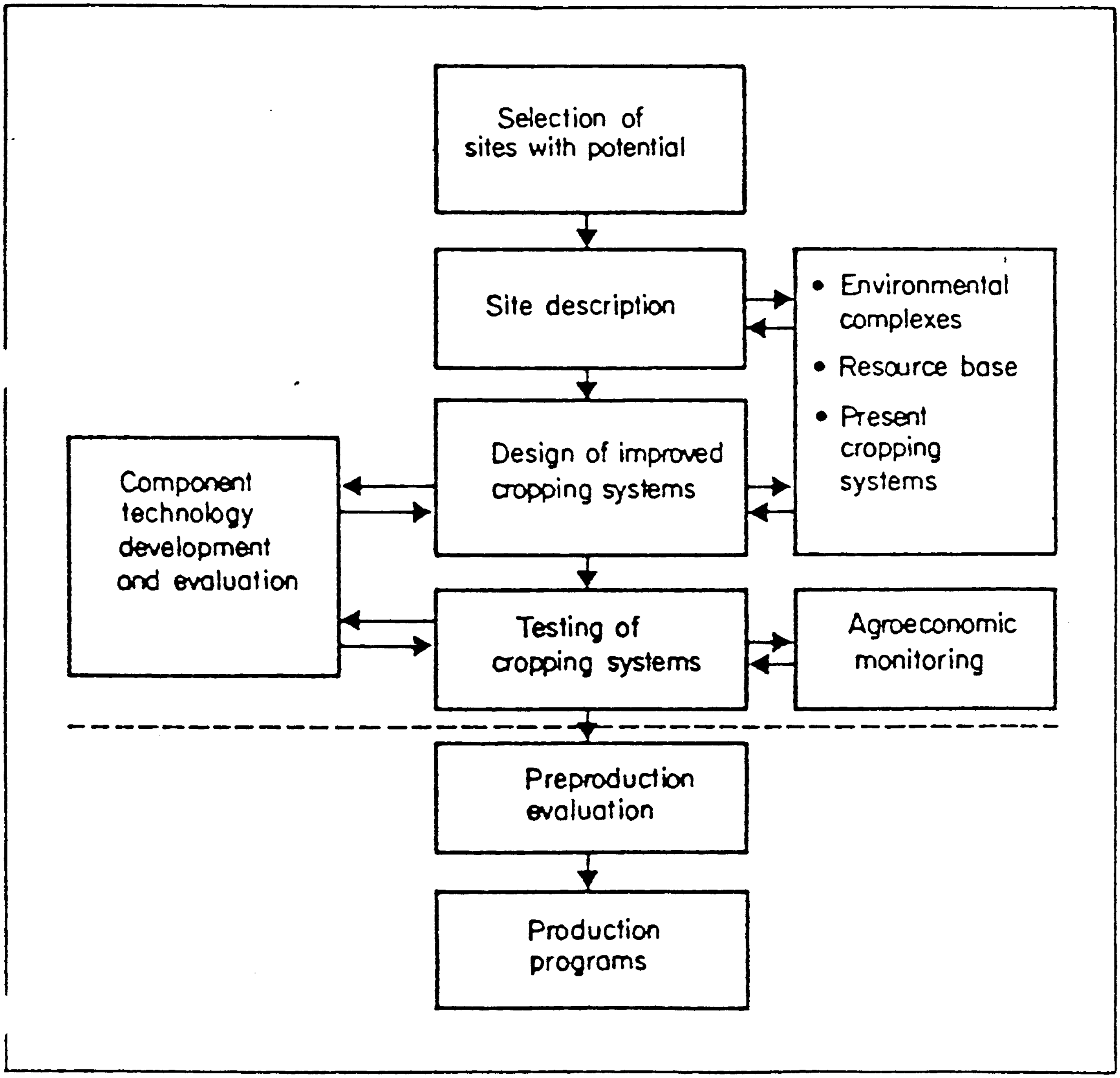
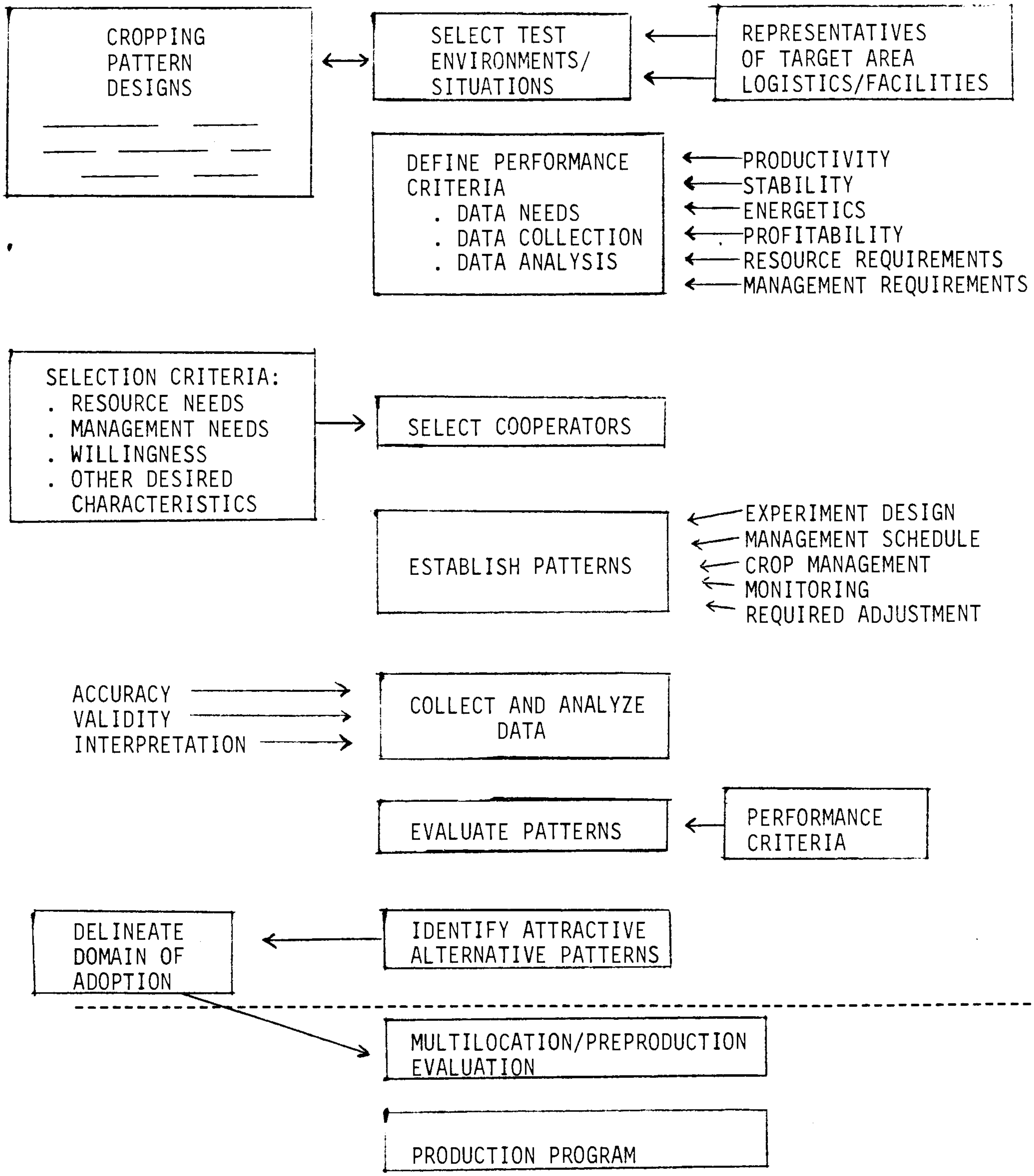


FIGURE 6

THE SEQUENCE OF EVENTS IN THE ON-FARM CROPPING PATTERN TESTING PROCESS



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